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CASE WESTERN RESERVE UNIVERSITY

MEMO

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Subject: **NASA Grant NAG 9-571**

FINAL REPORT, 31 JULY 1994

NOTE: The final budget report will be forwarded by the University

<u>(A) RESEARCH OBJECTIVES</u>: (1) To determine the frequency and velocity of rotational head perturbations that occur during natural locomotion in earth gravity. (2) To measure the cervico-ocular reflex (COR) and vestibulo-ocular reflex (VOR) during rotational trunk and head perturbations corresponding to those occurring during natural activities such as locomotion, while viewing a variety of moving or stationary targets.

<u>(B) METHODS</u>: (1) We measured 3-D head rotations during natural and treadmill walking using a Watson angular rate sensor. We studied 10 normal subjects and 2 patients with deficient vestibular function during natural walking through a distance of about 30 meters, while they attempted to view (A) a stationary target at optical infinity; (B) a target at a distance of 20 cm rigidly attached to the head. (2) We measured eye, trunk, and head rotations using the magnetic search coil technique. We measured COR and VOR gain while normal subjects and patients with vestibular or visual tracking deficits attempted to view (A) a stationary target or (B) a moving target (visual tracking). We used mathematical models to account for the observed cervico-visuo-vestibular interaction in our subjects and patients.

<u>(C) FINDINGS</u>: (A) Normal subjects and patients showed no significant change in the predominant frequency of head rotations in any plane during the two different viewing tasks. Mean peak head velocities also showed no difference during the two viewing conditions, except in the yaw plane in which values were greater during viewing the near target. We also compared natural locomotion with treadmill walking (in normal subjects) or walking in place (in patients). The predominant frequencies of head rotations were similar in the pitch plane during natural or treadmill walking; however, the peak velocities of pitch head rotations were substantially greater during natural walking. As a control experiment, subjects attempted to view an earth-fixed target at a distance of 20 cm while walking on the treadmill. No changes in head rotations were apparent compared with the head-fixed near viewing condition. One of two patients with deficient vestibular function showed modest increases of head velocity during natural walking compared with control subjects. In order to maintain visual fixation of a head-fixed display while walking, it is necessary to suppress vestibular eye movements. Our data indicate that the head rotations that induce vestibular eye movements are little affected by fixation of a head-fixed target, having predominant frequencies of 1-5 Hz, and peak velocities of 10-30 deg/sec during natural walking. [Results reported in Das et al., 1993; manuscript submitted] (B) Although we were able to resolve eye rotations of <0.05 degree, the COR was hardly measurable (gain was always less than 0.07). This finding, made with the most precise

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measurement technique used to date, suggests that the COR makes a negligible contribution to the stability of gaze in normal subjects during natural activities. [Results reported in Sawyer et al., 1994] In related studies we had found evidence for dynamic modulation of VOR gain by noting differences in responses to the onset and offset of head rotation in trials of the visually enhanced VOR, indicating that a linear superposition of smooth pursuit and VOR signals accounts for most but not all aspects of combined eye-head tracking. Specifically, a parametric adjustment of the VOR, consisting of a gain reduction of approximately 30%, contributes to eye-head tracking behavior. Furthermore, we had determined that in patients with brain stem or cerebellar disease, a simple superposition model failed to account for tracking behavior in most patients in any plane of rotation. Therefore, the COR is not likely to influence visuo-vestibular interaction, and the latter has non-linear characteristics that can be reliably modelled. In other, related studies, we studied other aspects of visuo-vestibular interaction, the relationship between eye movements and vision, and the cervico-ocular reflex.

(E) OPERATIONAL SIGNIFICANCE: (1) The recent development of light-weight head-fixed displays that can act as a computer screen are designed to provide the subject with displays and data during walking or motorized travel (including aerospace vehicles). The ability to clearly see such displays depends, in part, upon the stability of retinal images. During locomotion, head perturbations induce vestibular eye movements that are well suited to allow clear vision of earth-fixed targets. What this study demonstrates is that the head movements that occur during walking are not affected by viewing conditions, and so it falls to the brain to modulate the reflexive vestibular movements according to visual demands. (2) Under natural conditions combined movements of eye and head are used to track a moving target. One question that arises is how this is achieved -- solely through a visual tracking mechanism or by modulating the gain of the VOR, perhaps by addition of a COR signal. We have shown that the COR probably plays no role in normal subjects but that a non-visual modulation of the VOR contributes significantly. Since vestibular mechanisms are known to be changed after entry into, or after return from, microgravity, then subjects abilities to perform combined eye-head tracking movements are likely to be affected. Our studies have made it possible to develop and test a mathematical model for combined eye-head tracking that can be directly applied to account for measured performance (and symptoms) in astronauts either in flight or soon after return to earth.

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